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ABSTRACT:

Natural sites, monuments and historical artefacts are Cultural Heritage that must be properly managed to ensure their safeguard. Institutions and corporate body devoted to the Cultural Heritage management have the essential task of supervising them paying particular attention to their conservation, dissemination and fruition. In this regards, digital technologies through ICT (Information and Communication Technologies) and New Media represent useful tools which have to be used in suitable way. In this context, this contribution shares the methodology adopted for the case study of Serralunga d'Alba castle. In particular, the research project shows the process used for getting the digital model of the castle through HBIM (Historic Building Information Modeling) methodology and the development of a VR (Virtual Reality) model tour. The final project obtained is the result of a methodological approach that aimed to optimize time, costs and efforts.

1. INTRODUCTION

UNESCO (United Nations Educational, Scientific and Cultural Organization) defines Cultural Heritage as the legacy of both tangible (such as monuments, buildings, landscapes, natural places) and intangible heritages (such as traditions, languages, traditions, knowledge) which have been inherited from past generations.
According to the Italian laws, the main mission of organisations and institutions which operate in this field is to ensure that Cultural Heritage is safeguarded over time (D. Lgs. 42/2004) in order to be enjoyed by future generations. In particular, the conservation of physical artefacts takes place through appropriate maintenance activities and specific restoration works. With regards to the built heritage, the knowledge of the present state of the artefacts and the accurate management of building data, plays a key role. This aspect is truer considering big historical buildings or cultural sites composed of many buildings or heterogeneous artefacts. The absence of these aspects, often due to the lack of funds necessary for their application, implies the management of the architectural heritage according to the "cause-effect" approach (i.e. damage-intervention).
The second fundamental aspect that must be pursued by organisations of this sector regards the promotion and dissemination of Cultural Heritage. This objective includes all actions aimed at increasing the public usability of Cultural Heritage: not only in terms of physical accessibility by users, but also in terms of accessibility to cultural information. This concept considerably broadens the perspectives of usability because it aims to reach all categories of users developing an inclusive Cultural Heritage.

1.1 Towards Digital Cultural Heritage

In recent decades, continuous innovations in Computer Science have disrupted working methods and processes in many sectors. The branch that involves the intersection between ICT (Information and Communication Technologies) sector and the humanistic fields is defined as "Digital Humanities" (Bellotti et al., 2013). This innovation has been widely adopted by scientific community that deals with Cultural Heritage and, in the literature, it is known as "Virtual Heritage" or "Digital Cultural Heritage" (Addison, 2001). It represents the ICT solutions which address recordation, documentation and visualization issues applied to Cultural Heritage (Ruffino, 2018) (Fig. 1).

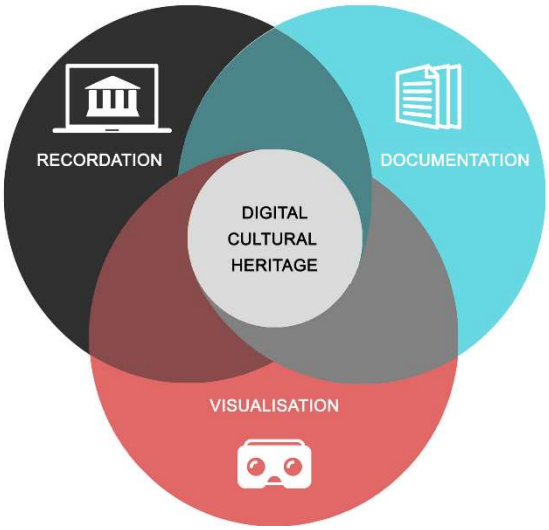

Figure 1. Use cases of digital cultural heritage (Ruffino, 2018)

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More specifically, Digital Technologies allow to achieve conservation goals of Cultural Heritage through advanced survey systems and 3D modeling tools for digital reconstruction of artefacts, information modeling platform for data management, Data-Base for archiving of historical documents and geospatial systems for historical draws mapping.
In addition, Digital Technologies allow to recreate objects, buildings or places that no longer exist making accessible also the lost Cultural Heritage due to natural effects or anthropogenic factors. Concerning this point and the promotion and dissemination aspects of Cultural Heritage, New Media are playing an important role. Their suitable usage allows to enhance the understanding of Cultural Heritage making them more accessible by visitors. Through these solutions, users can interact, participate and view cultural collections in novel and experiential ways (Sullivan, 2015). In this regard, VR (Virtual Reality) technologies represent the best solution to create Simulation and Serious Games (SSG) where the user can interact with the virtual world in immersive way.

In this context, this contribution shows the methodology adopted for the digitalisation of a medieval castle in order to aid its conservation and dissemination.

1.2 Features of the case study

The vineyard landscapes of Langhe-Roero and Monferrato are located in the southern part of the Piedmont region (Italy), between the Po River in the north and the Ligurian Appenines in the south, across a wide region of hills, framed by shallow valleys. This area included five distinct winegrowing areas and one castle, whose names are emblematic of profound and ancient expertise reflecting the relationship of man with his environment (Fig. 2): Part 1 – Langa of Barolo, Part 2 – Grinzane Cavour Castle, Part 3 – Hills of Barbaresco, Part 4 – Nizza Monferrato and Barbera, Part 5 – Canelli and Asti Spumante, Part 6 – Monferrato of the Infernot.

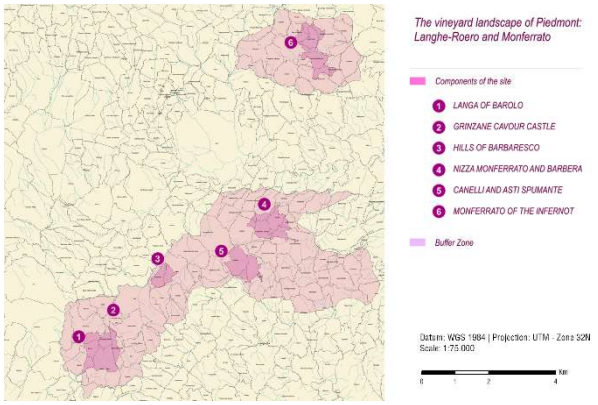

Figure 2. Components of UNESCO site

These zones express a slowly refined association between a diverse range of soil types, grape varieties that are often native, and suitable winemaking processes, and at the same time they offer panoramas of carefully cultivated hillsides, following ancient land divisions punctuated by buildings which provide structure to the visual space on the margins of the vineyards.
The property claims to be emblematic in the harmony and balance between the aesthetic qualities of its landscapes, the architectural and historic diversity of the built elements associated with the vineyards and viticulture, and an authentic and ancient art of winemaking. The vineyard landscapes of Langhe-Roero are nominated on the basis of cultural criteria (iii) and (v), in particular, landscapes of the Piedmont vineyards constitute an outstanding living testimony to winegrowing and winemaking traditions that have a very long history and that have evolved and been constantly improved right up to the present day. Simultaneously, these vineyards landscape represents a serial property for an outstanding and rare example of human interaction with the environment and representation of the changing.
The proposed research was applied to the case study of Serralunga d'Alba (Fig.3), municipality included in the Part 1 – Langa del Barolo - extremely celebrated and expertise known for its red wine - which produce Barolo DOCG from the Nebbiolo, a grape variety. Its landscape is composed of carefully kept vineyard plots, accompanied by a few fields of cereals and woods on slopes.

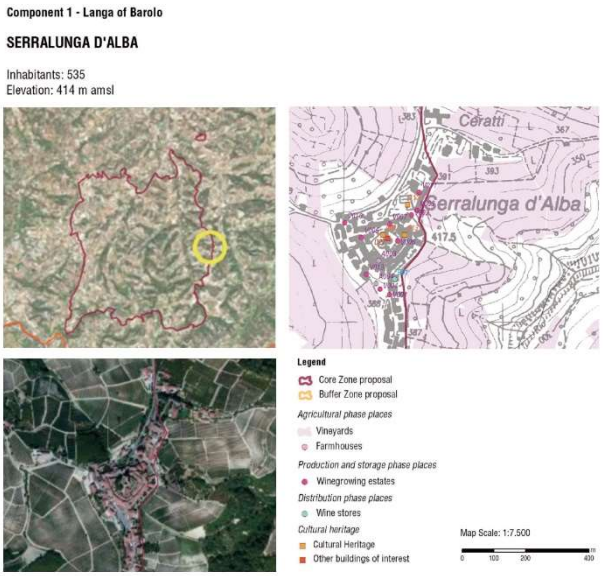

Figure 3. Case study location

The settlement consists of Medieval villages with their central castle, laid out in a circular basted arrangement, as to Serralunga d'Alba. The Castle of Serralunga d'Alba (Fig. 4) is considered one of the best conserved examples of 14th century noble castles in Piedmont: this castle represents a unique piece of history in Italy with an architectural structure of a French *donjon*.


Figure 4. Serralunga d'Alba castle and his historical village

In this context, the research project has been applied to an architectural structure strongly representative and most emblematic of the territory. This Castle express the cultural, residential, architectural, environmental and productive complexity that characterizes this region; for this reason, it must

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be protects and safeguarded. The project represents without distinction a monitoring tool, useful to the corporate body preceded for the protection of the architectural heritage, to allow and prevent critical situations in urban area and an inclusive solution to make accessible this historical artefact for everyone.

2. METHODOLOGY

The methodological approach adopted for the project development aims to optimise the process to achieve the objectives required. In this sense, the research project do not use the best solution suggested by literature review but attempts to identify processes usable by institution and organizations which manage these types of historical artefacts.

2.1 HBIM model development

2.1.1 Data collection stage: Given the case study considered and the objectives pursued, the digitalisation process was applied with HBIM (Historic Building Information Modeling) methodology.
Through digital information systems like BIM-based software is possible to product multi-purpose models that can be used for many usages (Dore et al., 2012). However, as the BIM methodology has been developed to support design, construction and management phases of new buildings, its application for the digitalisation of existing buildings presents additional difficulties (Del Giudice et al, 2013). The process of creating the information model is reversed: while in new constructions the digital model is created before its realization, for existing artefacts it is the model that must correspond to the real one.
In this context, in the digitalisation process of existing elements, the survey methods to get geometric data necessary for the modeling phase must be involved. Nowadays, laser scanning and photogrammetry technique are widely used for recording Cultural Heritage (Dore et al., 2012) and they allow to get point clouds with high accuracy. However, it is important to consider the following questions during the preliminary stages:

1. What is the purpose of the survey?
2. Can I avoid it?
3. What are data already available?

Therefore, the Superintendence was been involved to give coherent responses to the real needs of the main stakeholder who manages and conserves the castle.
Given the precondition mentioned above, the 3D model of the castle was developed using mainly CAD drawings available in the institution archives. These 2D conventional drawings (plans, elevations and sections) were developed from the restitution of a traditional architectural surveying carried out previously. These data are not the most suitable in terms of accuracy, however they still represent the most common free geometric data for the majority cultural heritages.
In this context, the correspondence between the digital twin and the real physical element was still an important aspect to verify. In this regard, a photogrammetric survey was carried out to obtain a point cloud of the exterior elements of the castle (Fig. 5).

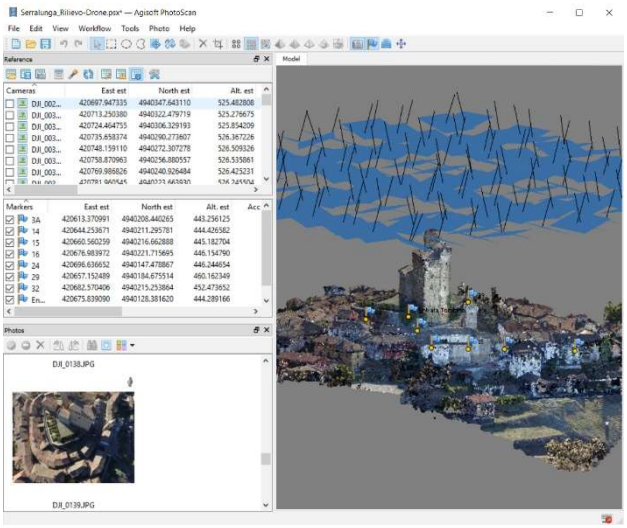

Figure 5. Photogrammetric processing and georeferencing phase

Once it was integrated with a GNSS (Global Navigation Satellite System) survey to get an accurate geospatial data, point cloud was imported into a BIM-based software during the modeling phase (Fig. 6). More specifically, point cloud assisted in verifying the perimeter of external walls, the heights of the elements (especially with regard to the towers), the slopes of the roofs, the correct position of the windows and all external elements.

Figure 6. Point cloud usage for supporting modeling stage

2.1.2 Modeling stage: During the development of the HBIM model, particular attention has been given to the modeling of castle components. To define a modeling standard of the HBIM model families, a similar approach of the surveying stage was executed:

1. What is the purpose of the HBIM model?
2. Which is the LOD (Level of Development) that meets the conservation and dissemination needs?
3. Which geometrical details should be created to use the HBIM model for the VR tour?

As far as the conservative aspects are concerned, the greatest attention was given to the information issues. The HBIM modeling for conservation is still representing a question to resolve. BIM-based platforms do not represent a suitable technique for heritage conservation therefore they are substituted for most conventional CAD (Computer Aided Design) tools or

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are integrated by specific software add-on (Pocobelli et al., 2018).
About the project in question, a different approach was developed taking into account the limits and the potentialities of the BIM-based platform used for the information modeling.
In this sense, all elements relevant for maintenance activities were created with specific parameters. In this way, all components are associated with data about: location of the element, type of degradation identified, type of intervention required, details of the last intervention executed.
It is important to highlight that, in order to create a solution with low modeling effort, parameters about degradation do not give any quantity or geometric data but are limited to “yes/no” parameters. This aspect had implications in the modeling criteria: elements such as the walls of the towers have been split into several parts to limit the portion considered and to associate different data to each of them (Fig. 7).

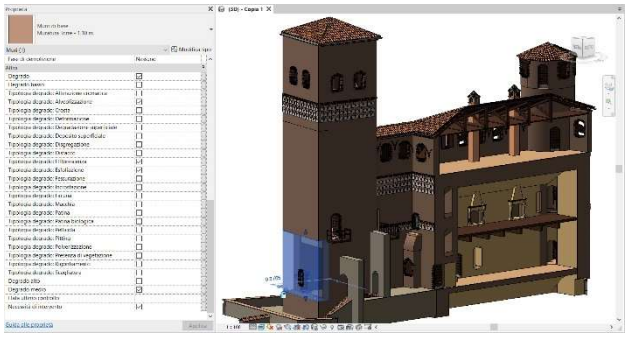

Figure 7. Setting of degradation parameters

Through this system, the Superintendence is able to be updated on the present state of conservation and maintenance of the historic building and its elements.

With regard to the use of the HBIM model for the development of a VR tour, the most important aspects to consider were the graphic and geometric issues.
Historic buildings like these are made up of many unique elements which can be reproduced in the digital model with high matching to the detriment of time, cost and effort. For this reason, modeling criteria adopted do not pay attention to represent graphic details of each real element. Rather, it is a modeling approach that simplifies the complexity of the real but that allows users to understand the correspondence with reality.

2.2 From HBIM to VR model tour

Similarly to what was done for the creation of the HBIM model, the tour development was carried out on the basis of the following guide questions:

1. What is the purpose of the VR model tour?
2. Who will be the users?
3. Which are digital technologies suitable to achieve project goals?

2.2.1 Tour purpose: Historical artefacts like the castle of Serralunga d'Alba are characterized by some factors that make them useable only certain persons. The structure is composed of many architectural barriers which do not allow the visit to disabled people, seniors or persons who must stay in a care home. In addition, some interesting places, such as the water tank or towers, are not included in the route of visit so cannot be seen. In this context, the main objective of the project is to overcome gaps above mentioned through a VR model tour which can supports the inclusion of the castle.

Features of the VR model tour: The application of digital technologies to Cultural Heritage allows to communicate well tangible and intangible through a three-dimensional reconstruction of input data taken from historical sources (Davardoust, 2016). Digital reconstruction can be applied to the real or the imaginary or that no longer exists (Wall, 2014).
In this sense, many solutions aim to create a digital version of the physical artefact with high accuracy so as to bring “virtuality” closer to reality. This approach is more suitable if the tour intends to reproduce something that no longer exists. Since the castle is still intact, creating a digital model that respects the details of all object surfaces would require a very high effort about texture issue. Moreover, it would risk of being a fake representation of the real situation (Fig. 8).

Figure 8. Immersive navigation through Autodesk LIVE

This aspect is even more true with regards to the context: the castle is located within a UNESCO site that, as such, cannot be omitted in the tour but it cannot be modeled.
In the other hand, virtual tours are generated through 360 spherical panorama applied to existing artifacts but they are limited in terms of interaction since the cyber environment is composed of pictures.
In this context, a VR model tour was developed. It can be defined as virtual tour based on a HBIM model. In other words, the solution proposed tries to integrate the features of both virtual tours and HBIM models.

2.2.2 Preliminary tests: Nowadays, tools to develop VR solutions are countless. Each of them has different characteristics, potentialities and limitations that must be explored and known in order to identify the most suitable solution for the objectives pursued.
Given the methodological premises of the project, firstly was tested the VR tools designed to be applied to BIM models. More specifically, having used Autodesk Revit as BIM-based software, the first tests were applied to Autodesk LIVE and Enscape™.
Autodesk LIVE has proven to be an excellent tool for immersive navigation of the HBIM model. Although it was a heavy project file, the response of the VR system to user movements was smooth and fast. However, the navigation system is limited to the command “Teleport”: the user can move the player in a point of the space in instantly way like it was a teleport.
With regard to Enscape™, it is a VR tool that interacts with the BIM model in real-time (Fig. 9). This is a solution developed for

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designers to support and show design decisions. In this case, the software provides two navigation modes called "FlyMode" and "WalkMode". In this way, the user can move the player around the space like he was flying or walking.

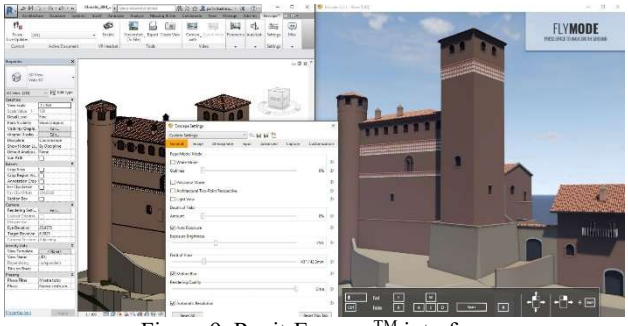

Figure 9. Revit-Enscape™ interface

In any case, both VR tools analysed presented some limitations in terms of customisation about player navigation modes and tour designing (route of the visit, cultural contents interaction). Therefore, these issues made them unusable for the realisation of a suitable tour.

2.2.3 Serious game development: Given results obtained by tools tested, the VR model tour was developed on Unity. Without entering into the merits of the software's features, Unity is a powerful open source game-engine developed by Unity Technology. Its wide use in the gaming sector allows to take advantage of rich libraries that make Unity a suitable tool to create serious games with high customizations.
The first step was the importing of 3D model from the BIM-based software to Unity. Given the recent partnership between Autodesk and Unity born in 2018, a specific plug-in called “Export to Unity” was used to export the 3D model from Revit.
This tool allows to get OBJ, MTL formats and image files which can be used directly on Unity.
Once 3D model was in Unity, first operations concerned the player and navigation mode settings. Given the case study features, the player movement was set with “Walking” mode. In this way, the user can visit the castle through the same point of view of a real visitor, like he was there. Using other settings such as “Fly” or “Teleport” mode, the user would not be able to appreciate some peculiarities such as the height and majesty of the castle, the stair slanting, the width of corridors, and so on.
Since the solution proposed is not just a system for exploring the 3D model, some panoramic pictures were imported in the serious game so that users are able to observe the reality corresponding to those point. For this purpose, a photo survey was done using an omnidirectional camera called RICOH THETA. This kind of camera allows to get 360 spherical panorama which can be visualised in VR systems. So, spherical images were applied to spheres set up in Unity in the same position in which the camera took the photo. More specifically, spherical images were imported as texture asset in Unity 3D. Then, they were connected to a *material* set to use the new Skybox/Panoramic shader by Unity 3D and use them as the sphere object *material*. Several Shaders were tested such as inside out shader, but the result is was not suitable as depicted in Fig 10.


Fig. 10

Therefore, the Unity skybox panoramic shader was used, which requires cube image conversion (Fig. 11).


Fig. 11

About user interaction within the panorama, Hotspot technique was implemented. It uses icon location where collider is applied such that if the player touches or collides with the hotspot, the view changes from 3D to the spherical panorama associated (Figg. 12-13-14).


Fig. 12. Player vision outside the Hotspot

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Fig. 13. Player vision into the Hotspot


Fig. 14. Immersive navigation of the VR model tour

Another aspect considered to improve the immersive spatial experience was the sound design through binaural audio: a specific kind of stereo audio in which the two different channels of audio signal are recorded on either side of a human head. The term binaural audio refers to audio in relation to two ears, which is the reason why we (humans and other animals) are able to distinguish sound directionality, or in other words sound localisation.
Sound localisation refers to a listener’s ability to identify the location or origin of a detected sound both in direction and distance. Binaural audio contributes greatly in creating a convincing immersive virtual experience.
Rayleigh's duplex theory states that since the left and right ears are on different sides of the head, each ear has a different coordinate in space (Macpherson et al., 2002). This means, a sound originating on the right side of the listener would travel form the source (in the speed of sound) and arrives on the listener's right ear first before arriving to the listener's left ear. This sound would also be of higher intensity (louder) on the right ear since the left ear is blocked by the listener's head. Interaural Time-Difference (ITD) and Interaural Intensity-Difference (IID) are time and loudness difference between the left and right ear. These two parameters allow to listener to localise sound in space. In order to employ the binaural audio into the VR tour, some environmental noises were applied. In particular, given the rich libraries available on the web, some sounds of typical birds that live in the territory around the case study were used.
To conclude, the last but not least point considered was the cultural content. About this, a simple solution was developed in order to make the VR tour suitable for many different kind of users. Thus, a system has been developed so that when the player enters into the panoramic spheres, he can listen the voice of a virtual guide that provides information like the real one.

3. CONCLUSIONS

Italy is a country rich in buildings and sites of great historical, cultural and environmental interest. Consequently, the institutions for managing and promoting them are aiming to explore new fields of methodology and technology to conserve and disseminate Cultural Heritage in an effective and efficient way.
In this context, this contribution tested a methodology based on usage of digital technologies currently available. The development of the project aimed to fulfil realistic needs of cultural heritage in terms of conservation and dissemination through an approach that minimized the effort needed to achieve them.
With regard to digital technologies aimed at conservation objectives, the HBIM methodology has proved to be a good tool for the digitization of the architectural artifact and for its management and conservation. In particular, the best benefits obtained by the system concern the space management and the degradation monitoring of main construction components. The HBIM model obtained has highlighted its potential in terms of database in which to converge many heterogeneous data. Lastly, its interoperability properties with game-engine software has made the use of geometric data for the development of the VR model tour possible.
In this sense, a serious game has been created in order to make the case study reachable by people who are unable to visit it in the traditional way. The VR model tour developed allows users to move freely in the castle in a virtual environment where they can enjoy the artifact and the real landscape through some 360 spherical panorama viewpoints.
In the end, particular attention was paid to sound issues in order to help users to immerse themself in the virtual world.
In conclusion, the contribution showed a possible methodological approach used for the castle of Serralunga d'Alba and similar historic buildings.

Aside from the peculiarities of the case study considered, the methodological approach has highlighted how the inclusion of cultural heritage must take into account the correlation and interaction that exists between cultural heritage, its users (tourists, institutions, Etc.) and digital technologies.

3.1 Future works

Next step will be to test the VR model tour by different kind of users in order to know its appreciation. The VR model tour will be adapted according to the results got.

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